

Storypoint Prediction - jirasoftware

September 9, 2024

1 Storypoint Prediction: Regression Approach

1.1 Preparation

```
[ ]: import os
import json
import random

import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import seaborn as sns
from scipy.sparse import csr_matrix, hstack, vstack

from sklearn.pipeline import Pipeline
from sklearn.preprocessing import RobustScaler
from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error, f1_score, precision_score, recall_score, accuracy_score
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.model_selection import learning_curve, validation_curve
from trainer import GridSearchCVTrainer

#['appceleratorstudio', 'aptanastudio', 'bamboo', 'clover',
# 'datamanagement', 'duracloud', 'jirasoftware', 'mesos',
# 'moodle', 'mule', 'mulestudio', 'springxd',
# 'talenddataquality', 'talendesb', 'titanium', 'usergrid']
project_name = 'jirasoftware'
```

1.1.1 Plot learning curve

```
[ ]: def plot_learning_curve(estimator, title, X, y, ylim=None, cv=None,
                             n_jobs=-1, train_sizes=np.linspace(.1, 1.0, 10)):
    plt.figure()          # Create new figure
    plt.title(title)      # Set title of the figure

    # Set y-axis limits: ylim=(min, max)
    if ylim is not None:
        plt.ylim(*ylim)
```

```

plt.xlabel("Training examples") # Set x-axis label
plt.ylabel("Score")             # Set y-axis label

# Generate learning curve data
train_sizes, train_scores, test_scores = learning_curve(
    estimator, X, y, cv=cv, n_jobs=n_jobs, train_sizes=train_sizes,
    ↪scoring='neg_mean_squared_error')

train_scores_mean = np.mean(train_scores, axis=1) # Calculate mean of
↪training scores
train_scores_std = np.std(train_scores, axis=1)   # Calculate standard
↪deviation of training scores
test_scores_mean = np.mean(test_scores, axis=1)   # Calculate mean of test
↪scores
test_scores_std = np.std(test_scores, axis=1)      # Calculate standard
↪deviation of test scores

plt.grid() # Display grid

# Fill the area between the mean training score and the mean +/- std
↪training score
plt.fill_between(train_sizes, train_scores_mean - train_scores_std,
                 train_scores_mean + train_scores_std, alpha=0.1,
                 color="r")

# Fill the area between the mean test score and the mean +/- std test score
plt.fill_between(train_sizes, test_scores_mean - test_scores_std,
                 test_scores_mean + test_scores_std, alpha=0.1, color="g")

# Plot mean training score as points
plt.plot(train_sizes, train_scores_mean, 'o-', color="r",
         label="Training score")
# Plot mean test score as points
plt.plot(train_sizes, test_scores_mean, 'o-', color="g",
         label="Validation score")

plt.legend(loc="best") # Display legend
return plt

```

1.1.2 Plot validation curve

```

[ ]: def plot_validation_curve(estimator, title, X, y, param_name, param_range,
                             y_lim=None, cv=10, n_jobs=-1):
    train_scores, val_scores = validation_curve(estimator=estimator, X=X, y=y,
                                                param_name=param_name,
    ↪param_range=param_range,

```

```

cv=cv, n_jobs=n_jobs,
    ↪
    ↪scoring='neg_mean_squared_error')

    # Calculate mean and standard deviation of training and validation scores
    train_mean = np.mean(train_scores, axis=1)
    tran_std = np.std(train_scores, axis=1)
    val_mean = np.mean(val_scores, axis=1)
    val_std = np.std(val_scores, axis=1)
    print(val_mean)

    # Plot train scores
    plt.plot(param_range, train_mean, color='r', marker='o', markersize=5,
    ↪label='Training score')
    plt.fill_between(param_range, train_mean + tran_std, train_mean - tran_std,
    ↪alpha=0.15, color='r')

    # Plot validation scores
    plt.plot(param_range, val_mean, color='g', linestyle='--', marker='s',
    ↪markersize=5, label='Validation score')
    plt.fill_between(param_range, val_mean + val_std, val_mean - val_std,
    ↪alpha=0.15, color='g')

    plt.title(title)        # Set title of the plot
    plt.grid()              # Display grid
    plt.xscale('log')        # Set x-axis scale to log
    plt.legend(loc='best')   # Display legend
    plt.xlabel('Parameter') # Set x-axis label
    plt.ylabel('Score')      # Set y-axis label

    # Set y-axis limits
    if y_lim != None:
        plt.ylim(y_lim)

    return plt

```

1.1.3 Evaluate model

```

[ ]: def evaluate_model(model, model_name, X_test, y_test, y_logscale=False,
    ↪save_directory=None):
    y_pred = model.predict(X_test)
    if(y_logscale):
        y_pred = np.exp(y_pred)

    lines = [model_name + '\s evaluation results:']

    mse = mean_squared_error(y_test, y_pred)

```

```

rmse = np.sqrt(mse)
mae = mean_absolute_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

lines.append(f' - Mean squared error:      {mse:.4f}')
lines.append(f' - Root mean squared error: {rmse:.4f}')
lines.append(f' - Mean absolute error:     {mae:.4f}')
lines.append(f' - R2 error:                {r2:.4f}')

y_pred = np.round(y_pred).astype(int)
f1 = f1_score(y_test, y_pred, average='weighted')
precision = precision_score(y_test, y_pred, average='weighted',
↪zero_division=0)
recall = recall_score(y_test, y_pred, average='weighted', zero_division=0)
accuracy = accuracy_score(y_test, y_pred)

lines.append(f' - F1 score:                {f1:.4f}')
lines.append(f' - Precision:              {precision:.4f}')
lines.append(f' - Recall:                 {recall:.4f}')
lines.append(f' - Accuracy:               {accuracy:.4f}')
lines.append('-----')
lines.append('')

# Save to file

if(save_directory != None):
    filename = save_directory + project_name + '.txt'
    directory = os.path.dirname(filename)
    if not os.path.exists(directory):
        os.makedirs(directory)
    with open(filename, 'a') as f:
        for line in lines:
            print(line)
            f.write(line + '\n')
else:
    for line in lines:
        print(line)

```

1.1.4 Set random seed

```

[ ]: # Set random seed for numpy
np.random.seed(42)

# Set random seed for random
random.seed(42)

# Set random seed for os

```

```
os.environ['PYTHONHASHSEED'] = '42'
```

1.2 Dataset set-up

1.2.1 Bag of Words preprocessing

This is a Bag of Words preprocess approach. I will use 2 CountVectorizer from sklearn to change title and description to two 2 vectors and then concatenate them together. In the rest of this notebook, I will use cross-validation instead hold-out. Therefore, I will join the validation set with training set.

```
[ ]: # Import and remove NaN value

data_train = pd.concat([pd.read_csv('data/' + project_name + '/' + project_name_
    ↪ '_train.csv'),
                        pd.read_csv('data/' + project_name + '/' + project_name_
    ↪ '_valid.csv')])
data_test = pd.read_csv('data/' + project_name + '/' + project_name + '_test.
    ↪ csv')

data_train['description'].replace(np.nan, '', inplace=True)
data_test['description'].replace(np.nan, '', inplace=True)

# Vectorize title
title_vectorizer = CountVectorizer(ngram_range=(1, 2), min_df=2)
title_vectorizer.fit(pd.concat([data_train['title'], data_test['title']]))

# Vectorize description
description_vectorizer = CountVectorizer(ngram_range=(1, 2), min_df=2)
description_vectorizer.fit(pd.concat([data_train['description'],
    ↪ data_test['description']]))

X_train = hstack([title_vectorizer.transform(data_train['title']).astype(float),
                  description_vectorizer.transform(data_train['description']).
    ↪ astype(float),
                  data_train['title'].apply(lambda x : len(x)).to_numpy().
    ↪ reshape(-1, 1),
                  data_train['description'].apply(lambda x : len(x)).to_numpy().
    ↪ reshape(-1, 1)
                  ])

y_train = data_train['storypoint'].to_numpy().astype(float)

X_test = hstack([title_vectorizer.transform(data_test['title']).astype(float),
```

```

        description_vectorizer.transform(data_test['description']).
↪astype(float),
        data_test['title'].apply(lambda x : len(x)).to_numpy().
↪reshape(-1, 1),
        data_test['description'].apply(lambda x : len(x)).to_numpy().
↪reshape(-1, 1)
    ])

y_test = data_test['storypoint'].to_numpy().astype(float)

```

```

[ ]: print('Check training dataset\'shape:', X_train.shape, y_train.shape)
     print('Check testing dataset\'shape:', X_test.shape, y_test.shape)

```

Check training dataset'shape: (258, 3815) (258,)

Check testing dataset'shape: (28, 3815) (28,)

I will use log-scale the label to get a normal distribution of it.

```

[ ]: y_train_log = np.log(y_train)

```

1.2.2 doc2vec preprocessing

This process is already prepared so I only need to import the thing

```

[ ]: # data_train = pd.concat([pd.read_csv('doc2vec/' + project_name + '/' +
↪project_name + '_train.csv'),
#                               pd.read_csv('doc2vec/' + project_name + '/' +
↪project_name + '_valid.csv')])
# data_test = pd.read_csv('doc2vec/' + project_name + '/' + project_name +
↪'_test.csv')

# X_train = np.vstack(data_train['doc2vec'].apply(lambda x: np.fromstring(x[1:
↪-1], sep=' ')).to_numpy())
# y_train = data_train['storypoint'].to_numpy().astype(int)

# X_test = np.vstack(data_test['doc2vec'].apply(lambda x: np.fromstring(x[1:
↪-1], sep=' ')).to_numpy())
# y_test = data_test['storypoint'].to_numpy().astype(int)

```

Check shape of the datasets

```

[ ]: # print('Check training dataset\'shape:', X_train.shape, y_train.shape)
     # print('Check testing dataset\'shape:', X_test.shape, y_test.shape)

```

```

[ ]: # y_train_log = np.log(y_train)

```

1.3 Model training

1.3.1 Linear Regressor

```
[ ]: from sklearn.linear_model import ElasticNet, Ridge
```

Ridge

```
[ ]: dict_param = {  
    'alpha': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],  
    'random_state': [42]  
}
```

```
[ ]: grid_search = GridSearchCVTrainer(name='Ridge', model=Ridge(),  
    ↪param_grid=dict_param,  
                                     cv=5, n_jobs=5, directory='settings/BoW/' +  
    ↪project_name + '/')  
grid_search.load_if_exists()  
grid_search.fit(X_train, y_train_log)  
  
ridge_model = grid_search.best_estimator_  
ridge_model.fit(X_train, y_train_log)
```

There is no checkpoint file for this model.

100%| | 9/9 [00:01<00:00, 8.41it/s]

```
[ ]: Ridge(alpha=1000, random_state=42)
```

```
[ ]: evaluate_model(ridge_model, 'Ridge model', X_test, y_test, y_logscale=True,  
    ↪save_directory='results/BoW/')
```

Ridge model's evaluation results:

- Mean squared error:	7.4531
- Root mean squared error:	2.7300
- Mean absolute error:	1.9263
- R2 error:	-0.0224
- F1 score:	0.0733
- Precision:	0.0527
- Recall:	0.1429
- Accuracy:	0.1429

```
[ ]: ridge_model.get_params()
```

```
[ ]: {'alpha': 1000,  
    'copy_X': True,  
    'fit_intercept': True,  
    'max_iter': None,
```

```
'positive': False,
'random_state': 42,
'solver': 'auto',
'tol': 0.0001}
```

Elastic net:

```
[ ]: dict_param['l1_ratio'] = [.2, .4, .6, .8, 1]
dict_param['max_iter'] = [5000]
```

```
[ ]: grid_search = GridSearchCVTrainer(name='Elastic Net', model=ElasticNet(),
    ↪param_grid=dict_param,
                                cv=5, n_jobs=5, directory='settings/BoW/' +
    ↪project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

elastic_model = grid_search.best_estimator_
elastic_model.fit(X_train, y_train_log)
```

There is no checkpoint file for this model.

100%| | 45/45 [00:34<00:00, 1.31it/s]

```
[ ]: ElasticNet(alpha=100, l1_ratio=0.4, max_iter=5000, random_state=42)
```

```
[ ]: evaluate_model(elastic_model, 'Elastic Net model', X_test, y_test,
    ↪y_logscale=True, save_directory='results/BoW/')
```

Elastic Net model's evaluation results:

```
- Mean squared error:      7.4623
- Root mean squared error: 2.7317
- Mean absolute error:     2.0998
- R2 error:                -0.0237
- F1 score:                0.0025
- Precision:               0.0013
- Recall:                  0.0357
- Accuracy:                0.0357
```

```
[ ]: elastic_model.get_params()
```

```
[ ]: {'alpha': 100,
'copy_X': True,
'fit_intercept': True,
'l1_ratio': 0.4,
'max_iter': 5000,
'positive': False,
```



```
'precompute': False,
'random_state': 42,
'selection': 'cyclic',
'tol': 0.0001,
'warm_start': False}
```

Choose final linear regressor model:

```
[ ]: if mean_squared_error(y_test, np.exp(ridge_model.predict(X_test))) < \
      mean_squared_error(y_test, np.exp(elastic_model.predict(X_test))):
      linear_model = ridge_model
else:
      linear_model = elastic_model
```

1.3.2 Support Vector Regressor

```
[ ]: from sklearn.svm import SVR
```

```
[ ]: dict_param = {
      'C': [.0001, .001, .01, .1, 1, 10, 100, 1000, 10000],
      'gamma': np.logspace(-9, 3, 13),
      'kernel': ['rbf']
    }
```

```
[ ]: grid_search = GridSearchCVTrainer(name="Support Vector Regressor", model=SVR(),
    ↪param_grid=dict_param,
    cv=5, n_jobs=5, directory='settings/BoW/' +
    ↪project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

svr_model = grid_search.best_estimator_
svr_model.fit(X_train, y_train_log)
```

0it [00:00, ?it/s]

```
[ ]: SVR(C=0.1, gamma=10.0)
```

```
[ ]: evaluate_model(svr_model, 'SVR model', X_test, y_test, y_logscale=True,
    ↪save_directory='results/BoW/')
```

SVR model's evaluation results:

```
- Mean squared error:      7.5342
- Root mean squared error: 2.7449
- Mean absolute error:     2.1449
- R2 error:                -0.0336
- F1 score:                0.0025
- Precision:               0.0013
- Recall:                  0.0357
```

- Accuracy: 0.0357

```
[ ]: svr_model.get_params()
```

```
[ ]: {'C': 0.1,  
      'cache_size': 200,  
      'coef0': 0.0,  
      'degree': 3,  
      'epsilon': 0.1,  
      'gamma': 10.0,  
      'kernel': 'rbf',  
      'max_iter': -1,  
      'shrinking': True,  
      'tol': 0.001,  
      'verbose': False}
```

1.3.3 Random Forest Regressor

```
[ ]: from sklearn.ensemble import RandomForestRegressor
```

```
[ ]: dict_param = {  
      'max_depth' : [1000, 2000, 5000],  
      'min_samples_split': [25, 200, 1000],  
      'min_samples_leaf': [1, 2, 3, 4],  
      'max_features': [50, 100, 200],  
      'n_estimators': [1024],  
      'random_state': [42]  
    }
```

```
[ ]: grid_search = GridSearchCVTrainer(name="Random Forest Regressor",  
                                       model=RandomForestRegressor(),  
                                       param_grid=dict_param, cv = 5, n_jobs=-1,  
                                       directory='settings/BoW/' + project_name + '/'  
                                       ↪)  
grid_search.load_if_exists()  
grid_search.fit(X_train, y_train_log)  
  
rfr_model = grid_search.best_estimator_  
rfr_model.fit(X_train, y_train_log)
```

Oit [00:00, ?it/s]

```
[ ]: RandomForestRegressor(max_depth=1000, max_features=200, min_samples_split=25,  
                          n_estimators=1024, random_state=42)
```

```
[ ]: evaluate_model(rfr_model, 'Random Forest model', X_test, y_test,
    ↪y_logscale=True, save_directory='results/BoW/')

```

Random Forest model's evaluation results:

```
- Mean squared error:      6.8756
- Root mean squared error: 2.6221
- Mean absolute error:     1.8019
- R2 error:                0.0568
- F1 score:                0.1265
- Precision:               0.0869
- Recall:                  0.2500
- Accuracy:                0.2500
-----

```

```
[ ]: rfr_model.get_params()

```

```
[ ]: {'bootstrap': True,
      'ccp_alpha': 0.0,
      'criterion': 'squared_error',
      'max_depth': 1000,
      'max_features': 200,
      'max_leaf_nodes': None,
      'max_samples': None,
      'min_impurity_decrease': 0.0,
      'min_samples_leaf': 1,
      'min_samples_split': 25,
      'min_weight_fraction_leaf': 0.0,
      'monotonic_cst': None,
      'n_estimators': 1024,
      'n_jobs': None,
      'oob_score': False,
      'random_state': 42,
      'verbose': 0,
      'warm_start': False}

```

1.3.4 XGBoost

```
[ ]: from xgboost import XGBRegressor

```

```
[ ]: dict_param = {
      'eta' : np.linspace(0.01, 0.2, 3),
      'gamma': np.logspace(-2, 2, 5),
      'max_depth': np.asarray([3, 5, 7, 9]).tolist(),
      'min_child_weight': np.logspace(-2, 2, 5),
      'subsample': np.asarray([0.5, .1]),
      'reg_alpha': np.asarray([0.0, 0.05]),
      'n_estimators': np.asarray([10, 20, 50, 100]).tolist(),
    }

```

```
    'random_state': [42]
}
```

```
[ ]: grid_search = GridSearchCVTrainer(name='XGBoost_
    ↳Regressor', model=XGBRegressor(), param_grid=dict_param,
                                cv = 5, n_jobs=2, directory='settings/BoW/' +
    ↳project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

xgb_model = grid_search.best_estimator_
xgb_model.fit(X_train, y_train_log)
```

Oit [00:00, ?it/s]

```
[ ]: XGBRegressor(base_score=None, booster=None, callbacks=None,
                  colsample_bylevel=None, colsample_bynode=None,
                  colsample_bytree=None, device=None, early_stopping_rounds=None,
                  enable_categorical=False, eta=0.105, eval_metric=None,
                  feature_types=None, gamma=0.1, grow_policy=None,
                  importance_type=None, interaction_constraints=None,
                  learning_rate=None, max_bin=None, max_cat_threshold=None,
                  max_cat_to_onehot=None, max_delta_step=None, max_depth=3,
                  max_leaves=None, min_child_weight=0.01, missing=nan,
                  monotone_constraints=None, multi_strategy=None, n_estimators=20,
                  n_jobs=None, num_parallel_tree=None, ...)
```

```
[ ]: evaluate_model(xgb_model, 'XGBoost Regressor model', X_test, y_test,
    ↳y_logscale=True, save_directory='results/BoW/')
```

XGBoost Regressor model's evaluation results:

```
- Mean squared error:      7.6232
- Root mean squared error: 2.7610
- Mean absolute error:     2.0185
- R2 error:                -0.0458
- F1 score:                0.0350
- Precision:               0.0298
- Recall:                  0.0714
- Accuracy:                0.0714
```

```
[ ]: xgb_model.get_params()
```

```
[ ]: {'objective': 'reg:squarederror',
      'base_score': None,
      'booster': None,
      'callbacks': None,
```

```

'colsample_bylevel': None,
'colsample_bynode': None,
'colsample_bytree': None,
'device': None,
'early_stopping_rounds': None,
'enable_categorical': False,
'eval_metric': None,
'feature_types': None,
'gamma': 0.1,
'grow_policy': None,
'importance_type': None,
'interaction_constraints': None,
'learning_rate': None,
'max_bin': None,
'max_cat_threshold': None,
'max_cat_to_onehot': None,
'max_delta_step': None,
'max_depth': 3,
'max_leaves': None,
'min_child_weight': 0.01,
'missing': nan,
'monotone_constraints': None,
'multi_strategy': None,
'n_estimators': 20,
'n_jobs': None,
'num_parallel_tree': None,
'random_state': 42,
'reg_alpha': 0.0,
'reg_lambda': None,
'sampling_method': None,
'scale_pos_weight': None,
'subsample': 0.5,
'tree_method': None,
'validate_parameters': None,
'verbosity': None,
'eta': 0.105}

```

1.3.5 LightGBM

```

[ ]: from lightgbm import LGBMRegressor
     from sklearn.model_selection import ParameterSampler

```

```

[ ]: dict_param = {
      'n_estimator': [10, 20, 50, 100, 200, 500],
      'max_depth': np.asarray([5, 7, 9, 11, 13]).tolist(),
      'num_leaves': ((np.power(2, np.asarray([5, 7, 9, 11, 13]))) - 1) * (0.55 +
↪ (0.65 - 0.55) * np.random.rand(5))).astype(int).tolist(),

```

```

    'min_data_in_leaf': np.linspace(100, 1000, 4).astype(int).tolist(),
    'feature_fraction': np.linspace(0.6, 1, 3),
    'bagging_fraction': np.linspace(0.6, 1, 3),
    'learning_rate': [0.01],
    'verbose': [-1],
    'random_state': [42]
}

def custom_sampler(param_grid):
    for params in ParameterSampler(param_grid, n_iter=1e9):
        range_num_leaves = ((0.5 * (2**params['max_depth'] - 1)), (0.7 *
↪(2**params['max_depth']) - 1))
        if (range_num_leaves[0] <= params['num_leaves'] <= range_num_leaves[1]):
            for key, value in params.items():
                params[key] = [value]
            yield params

```

```

[ ]: grid_search = GridSearchCVTrainer(name='LightGBM Regressor',
↪model=LGBMRegressor(),

                                param_grid=list(custom_sampler(dict_param)), cv
↪= 5, n_jobs=1,

                                directory='settings/BoW/' + project_name + '/')
grid_search.load_if_exists()
grid_search.fit(X_train, y_train_log)

lgbmr_model = grid_search.best_estimator_
lgbmr_model.fit(X_train, y_train_log)

```

c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-packages\sklearn\model_selection_search.py:320: UserWarning: The total space of parameters 5400 is smaller than n_iter=1000000000. Running 5400 iterations. For exhaustive searches, use GridSearchCV.

```
warnings.warn(
Oit [00:00, ?it/s]
```

```

[ ]: LGBMRegressor(bagging_fraction=0.6, feature_fraction=0.6, learning_rate=0.01,
                    max_depth=5, min_data_in_leaf=100, n_estimator=10, num_leaves=19,
                    random_state=42, verbose=-1)

```

```

[ ]: evaluate_model(lgbmr_model, 'LightGBM regressor model', X_test, y_test,
↪y_logscale=True, save_directory='results/BoW/')

```

LightGBM regressor model's evaluation results:

```

- Mean squared error:      7.7378
- Root mean squared error: 2.7817
- Mean absolute error:     2.0697
- R2 error:                -0.0615
- F1 score:                0.0031

```

```
- Precision:          0.0016
- Recall:            0.0357
- Accuracy:          0.0357
```

```
c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\lightgbm\basic.py:1218: UserWarning: Converting data to scipy sparse
matrix.
```

```
_log_warning("Converting data to scipy sparse matrix.")
```

```
[ ]: lgbmr_model.get_params()
```

```
[ ]: {'boosting_type': 'gbdt',
      'class_weight': None,
      'colsample_bytree': 1.0,
      'importance_type': 'split',
      'learning_rate': 0.01,
      'max_depth': 5,
      'min_child_samples': 20,
      'min_child_weight': 0.001,
      'min_split_gain': 0.0,
      'n_estimators': 100,
      'n_jobs': None,
      'num_leaves': 19,
      'objective': None,
      'random_state': 42,
      'reg_alpha': 0.0,
      'reg_lambda': 0.0,
      'subsample': 1.0,
      'subsample_for_bin': 200000,
      'subsample_freq': 0,
      'verbose': -1,
      'n_estimator': 10,
      'min_data_in_leaf': 100,
      'feature_fraction': 0.6,
      'bagging_fraction': 0.6}
```

1.3.6 Stacked model:

```
[ ]: from mlxtend.regressor import StackingCVRegressor
```

Define component models:

```
[ ]: trained_models = [linear_model, svr_model, rfr_model, xgb_model, lgbmr_model]
```

Define blended model:

```
[ ]: stack_gen = StackingCVRegressor(regressors=tuple(trained_models),
                                     meta_regressor=trained_models[np.
                                     ↪argmin([mean_squared_error(np.exp(model.predict(X_test)), y_test) for model_
                                     ↪in trained_models])),
                                     use_features_in_secondary=True, n_jobs=-1,
                                     ↪random_state=42)
print(stack_gen)
```

```
StackingCVRegressor(meta_regressor=RandomForestRegressor(max_depth=1000,
                                                         max_features=200,
                                                         min_samples_split=25,
                                                         n_estimators=1024,
                                                         random_state=42),
                   n_jobs=-1, random_state=42,
                   regressors=(Ridge(alpha=1000, random_state=42),
                               SVR(C=0.1, gamma=10.0),
                               RandomForestRegressor(max_depth=1000,
                                                         max_features=200,
                                                         min_samples_split=25,
                                                         n_estimators=1024,
                                                         random_state=42),
                               X...
                               max_delta_step=None, max_depth=3,
                               max_leaves=None,
                               min_child_weight=0.01, missing=nan,
                               monotone_constraints=None,
                               multi_strategy=None,
                               n_estimators=20, n_jobs=None,
                               num_parallel_tree=None, ...),
                               LGBMRegressor(bagging_fraction=0.6,
                                               feature_fraction=0.6,
                                               learning_rate=0.01, max_depth=5,
                                               min_data_in_leaf=100,
                                               n_estimator=10, num_leaves=19,
                                               random_state=42, verbose=-1)),
                   use_features_in_secondary=True)

c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\lightgbm\basic.py:1218: UserWarning: Converting data to scipy sparse
matrix.
  _log_warning("Converting data to scipy sparse matrix.")
```

```
[ ]: stack_gen.fit(X_train, y_train_log)
```

```
[ ]: StackingCVRegressor(meta_regressor=RandomForestRegressor(max_depth=1000,
                                                         max_features=200,
                                                         min_samples_split=25,
                                                         n_estimators=1024,
```



```

random_state=42),
n_jobs=-1, random_state=42,
regressors=(Ridge(alpha=1000, random_state=42),
             SVR(C=0.1, gamma=10.0),
             RandomForestRegressor(max_depth=1000,
                                   max_features=200,
                                   min_samples_split=25,
                                   n_estimators=1024,
                                   random_state=42),
             X...
             max_delta_step=None, max_depth=3,
             max_leaves=None,
             min_child_weight=0.01, missing=nan,
             monotone_constraints=None,
             multi_strategy=None,
             n_estimators=20, n_jobs=None,
             num_parallel_tree=None, ...),
             LGBMRegressor(bagging_fraction=0.6,
                             feature_fraction=0.6,
                             learning_rate=0.01, max_depth=5,
                             min_data_in_leaf=100,
                             n_estimator=10, num_leaves=19,
                             random_state=42, verbose=-1)),
             use_features_in_secondary=True)

```

```

[ ]: evaluate_model(stack_gen, 'Stacking model', X_test, y_test, y_logscale=True,
    ↪save_directory='results/BoW/')

```

Stacking model's evaluation results:

```

- Mean squared error:      6.8068
- Root mean squared error: 2.6090
- Mean absolute error:     1.7552
- R2 error:                0.0662
- F1 score:                0.1566
- Precision:               0.2622
- Recall:                  0.2143
- Accuracy:                0.2143

```

```

c:\Users\aupho\AppData\Local\Programs\Python\Python311\Lib\site-
packages\lightgbm\basic.py:1218: UserWarning: Converting data to scipy sparse
matrix.

```

```

_log_warning("Converting data to scipy sparse matrix.")

```

```

[ ]: stack_gen.get_params()

```

```
[ ]: {'cv': 5,
      'meta_regressor__bootstrap': True,
      'meta_regressor__ccp_alpha': 0.0,
      'meta_regressor__criterion': 'squared_error',
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      'meta_regressor__max_features': 200,
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      'meta_regressor__max_samples': None,
      'meta_regressor__min_impurity_decrease': 0.0,
      'meta_regressor__min_samples_leaf': 1,
      'meta_regressor__min_samples_split': 25,
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      'meta_regressor__n_estimators': 1024,
      'meta_regressor__n_jobs': None,
      'meta_regressor__oob_score': False,
      'meta_regressor__random_state': 42,
      'meta_regressor__verbose': 0,
      'meta_regressor__warm_start': False,
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min_samples_split=25,
                                     n_estimators=1024, random_state=42),
      'multi_output': False,
      'n_jobs': -1,
      'pre_dispatch': '2*n_jobs',
      'random_state': 42,
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                     SVR(C=0.1, gamma=10.0),
                     RandomForestRegressor(max_depth=1000, max_features=200, min_samples_split=25,
                                     n_estimators=1024, random_state=42),
                     XGBRegressor(base_score=None, booster=None, callbacks=None,
                                     colsample_bylevel=None, colsample_bynode=None,
                                     colsample_bytree=None, device=None, early_stopping_rounds=None,
                                     enable_categorical=False, eta=0.105, eval_metric=None,
                                     feature_types=None, gamma=0.1, grow_policy=None,
                                     importance_type=None, interaction_constraints=None,
                                     learning_rate=None, max_bin=None, max_cat_threshold=None,
                                     max_cat_to_onehot=None, max_delta_step=None, max_depth=3,
                                     max_leaves=None, min_child_weight=0.01, missing=nan,
                                     monotone_constraints=None, multi_strategy=None, n_estimators=20,
                                     n_jobs=None, num_parallel_tree=None, ...),
                     LGBMRegressor(bagging_fraction=0.6, feature_fraction=0.6, learning_rate=0.01,
                                     max_depth=5, min_data_in_leaf=100, n_estimator=10,
num_leaves=19,
                                     random_state=42, verbose=-1)),
      'shuffle': True,
```

```

'store_train_meta_features': False,
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'verbose': 0,
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'svr': SVR(C=0.1, gamma=10.0),
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max_features=200, min_samples_split=25,
n_estimators=1024, random_state=42),
'xgbregressor': XGBRegressor(base_score=None, booster=None, callbacks=None,
colsample_bylevel=None, colsample_bynode=None,
colsample_bytree=None, device=None, early_stopping_rounds=None,
enable_categorical=False, eta=0.105, eval_metric=None,
feature_types=None, gamma=0.1, grow_policy=None,
importance_type=None, interaction_constraints=None,
learning_rate=None, max_bin=None, max_cat_threshold=None,
max_cat_to_onehot=None, max_delta_step=None, max_depth=3,
max_leaves=None, min_child_weight=0.01, missing=nan,
monotone_constraints=None, multi_strategy=None, n_estimators=20,
n_jobs=None, num_parallel_tree=None, ...),
'lgbmregressor': LGBMRegressor(bagging_fraction=0.6, feature_fraction=0.6,
learning_rate=0.01,
max_depth=5, min_data_in_leaf=100, n_estimator=10, num_leaves=19,
random_state=42, verbose=-1),
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'ridge__copy_X': True,
'ridge__fit_intercept': True,
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'ridge__tol': 0.0001,
'svr__C': 0.1,
'svr__cache_size': 200,
'svr__coef0': 0.0,
'svr__degree': 3,
'svr__epsilon': 0.1,
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'svr__kernel': 'rbf',
'svr__max_iter': -1,
'svr__shrinking': True,
'svr__tol': 0.001,
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'randomforestregressor__max_depth': 1000,
'randomforestregressor__max_features': 200,

```

```
'randomforestregressor__max_leaf_nodes': None,
'randomforestregressor__max_samples': None,
'randomforestregressor__min_impurity_decrease': 0.0,
'randomforestregressor__min_samples_leaf': 1,
'randomforestregressor__min_samples_split': 25,
'randomforestregressor__min_weight_fraction_leaf': 0.0,
'randomforestregressor__monotonic_cst': None,
'randomforestregressor__n_estimators': 1024,
'randomforestregressor__n_jobs': None,
'randomforestregressor__oob_score': False,
'randomforestregressor__random_state': 42,
'randomforestregressor__verbose': 0,
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'xgbregressor__base_score': None,
'xgbregressor__booster': None,
'xgbregressor__callbacks': None,
'xgbregressor__colsample_bylevel': None,
'xgbregressor__colsample_bynode': None,
'xgbregressor__colsample_bytree': None,
'xgbregressor__device': None,
'xgbregressor__early_stopping_rounds': None,
'xgbregressor__enable_categorical': False,
'xgbregressor__eval_metric': None,
'xgbregressor__feature_types': None,
'xgbregressor__gamma': 0.1,
'xgbregressor__grow_policy': None,
'xgbregressor__importance_type': None,
'xgbregressor__interaction_constraints': None,
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'xgbregressor__max_bin': None,
'xgbregressor__max_cat_threshold': None,
'xgbregressor__max_cat_to_onehot': None,
'xgbregressor__max_delta_step': None,
'xgbregressor__max_depth': 3,
'xgbregressor__max_leaves': None,
'xgbregressor__min_child_weight': 0.01,
'xgbregressor__missing': nan,
'xgbregressor__monotone_constraints': None,
'xgbregressor__multi_strategy': None,
'xgbregressor__n_estimators': 20,
'xgbregressor__n_jobs': None,
'xgbregressor__num_parallel_tree': None,
'xgbregressor__random_state': 42,
'xgbregressor__reg_alpha': 0.0,
'xgbregressor__reg_lambda': None,
'xgbregressor__sampling_method': None,
```

```
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'xgbregressor__subsample': 0.5,
'xgbregressor__tree_method': None,
'xgbregressor__validate_parameters': None,
'xgbregressor__verbosity': None,
'xgbregressor__eta': 0.105,
'lgbmregressor__boosting_type': 'gbdt',
'lgbmregressor__class_weight': None,
'lgbmregressor__colsample_bytree': 1.0,
'lgbmregressor__importance_type': 'split',
'lgbmregressor__learning_rate': 0.01,
'lgbmregressor__max_depth': 5,
'lgbmregressor__min_child_samples': 20,
'lgbmregressor__min_child_weight': 0.001,
'lgbmregressor__min_split_gain': 0.0,
'lgbmregressor__n_estimators': 100,
'lgbmregressor__n_jobs': None,
'lgbmregressor__num_leaves': 19,
'lgbmregressor__objective': None,
'lgbmregressor__random_state': 42,
'lgbmregressor__reg_alpha': 0.0,
'lgbmregressor__reg_lambda': 0.0,
'lgbmregressor__subsample': 1.0,
'lgbmregressor__subsample_for_bin': 200000,
'lgbmregressor__subsample_freq': 0,
'lgbmregressor__verbose': -1,
'lgbmregressor__n_estimator': 10,
'lgbmregressor__min_data_in_leaf': 100,
'lgbmregressor__feature_fraction': 0.6,
'lgbmregressor__bagging_fraction': 0.6}
```